Letters to the Editor

Octave for SWR (Jan/Feb 2009) and More Octave for SWR (Jan/Feb 2014)

Hi Larry,

My *QEX* articles "Octave for SWR" (Jan/Feb, 2009) and "More Octave for SWR" (Jan/Feb, 2014) make reference to a figure that has appeared in the *ARRL Handbooks* and *ARRL Antenna Books* for many years.[1, 2] The figure appears as Figure 20.4 in the 2013 *ARRL Handbook* and as Figure 23.14(A) in the 22nd Edition of *The ARRL Antenna Book*. The figure relates SWR and matched line loss to the additional loss caused by an SWR of greater than 1:1 at the load.

In the 2014 and later *ARRL Handbook*, the figure was replaced by one that yields total line loss, including matched loss, plus the additional loss caused by SWR, rather than just the added line loss. The revised Figure appears as Figure 20.4 in the 2015 *ARRL Handbook*.

The new figure requires no changes in the text or math in the *QEX* articles, and the old figure as reprinted in the two articles is still a valid tool. Just be aware that the figure in the current *ARRL Handbook* yields the same information, but in a slightly different form.

The new figure has the advantage that it yields a quantity — total line loss — that is in accord with the text and math in *The ARRL Handbook*.

I do have some concerns about the labels in the new *Handbook* Figure. For many years, dating as far back as 1952 or earlier, *The ARRL Handbooks* have included a figure that yields the loss that is added to the matched line loss when a transmission line is terminated in other than its characteristic impedance. In the 2013 and older *Handbooks*, the figure caption begins: "Fig. 20.4 — Increase in line loss due to standing waves (SWR) ..." The abscissa of the figure is labeled "Line Loss in dB When Matched" and the ordinate is labeled "Additional Loss in dB Caused by Standing Waves."

The figure has been very useful, but it yields only the *increase* in line loss caused by SWR while the accompanying equation (Equation 11 on Page 20.5 of the 2013 *Handbook*) and the text deal with the total line loss, which is equal to the matched line loss plus the added loss due to SWR.

In the 2014 *Handbook*, and continuing with the 2015 Edition, the figure has been revised to yield the total line loss, rather than the additional line loss due to SWR. This change brings the figure into conformance with the accompanying text and math.

There are two problems with the new figure, though: the ordinate is labeled "Line Attenuation (dB)" and the caption begins with "Figure 20.4 — Total insertion loss ..."

There are several measures of loss that are commonly used in connection with transmission lines: insertion loss, transducer loss, attenuation, and line loss. All four are carefully defined in various references, including the *IEEE Dictionary of Electrical and Electronics Terms*, where "line loss" is termed "power loss," as it is sometimes called elsewhere.[3] I'll summarize the definitions here, particularizing them to the case of a transmitter (source), transmission line and antenna (load):

Insertion loss: the ratio between the power delivered by the source to the load when the two are connected directly and the power delivered to the same load when a particular transmission line is interposed between the source and the load.

Transducer loss: the ratio between the maximum power that a particular source can deliver to a load selected to maximize the power absorbed (conjugate match) and the power that is delivered to a specified load by the same source through a particular transmission line.

Attenuation: the ratio between either voltages or currents at two points along a transmission line, usually a line with no reflections. When divided by the distance between the two points, this measure is the real part of the complex propagation constant.

Line loss: the ratio between the power delivered by the source to the transmission line and the power delivered by the transmission line to the load.

All these measure of loss are generally expressed in dB, but sometimes in nepers. Note that, for perfectly matched resistive sources, lines, and loads (SWR = 1:1 at all points), the various measures converge to the same value when the points measured for attenuation are at the source and the load.

I presented mathematical comparisons of insertion loss, transducer loss, and line loss in "Octave for SWR". (See Note 1.) I showed that the equation and figure in the *Handbook* and the *Antenna Book* treat line loss rather than insertion loss or transducer loss. This is an important distinction because insertion loss and transducer loss are functions of the impedance of the source, the characteristic impedance of the line, and the impedance of the load. Line loss involves only the characteristic impedance of the line and the impedance of the load. Line loss "sees" the power from the source, but doesn't care about the impedance of the source.

Using *line loss* makes possible the use of a relatively simple graph to relate matched line loss to total line loss in the presence of an SWR greater than 1:1. Pages 569 through 573 of *Reference Data for Radio Engineers*, on the other hand, provide equations and alignment charts for calculating transducer loss and, along with it, line loss.[4] The alignment chart on page 573 duplicates the functionality of the older added loss graph in the pre-2014 *Handbooks* and the current (22nd Edition) *Antenna Book*. The legend for the alignment chart notes that it disregards the impedance of the source, as should be the case for line loss.

The text and equations in *Reference Data for Radio Engineers* show that the mathematical or graphical procedures for determining insertion loss or transducer loss are more complicated than are the corresponding determinations of line loss.

Insertion loss and transducer loss are heavily used in telecommunications engineering, where the source and load impedances are generally known and are well controlled where accuracy of information transfer is the objective. For radio transmitters, though, where power efficiency is important, the source impedance is generally not well known and must be below the value of the "50 Ω" label on the output connector or the transmitter's final amplifier will not be capable of reasonable Class AB1, AB2, or C performance. A 50 Ω resistive output impedance would yield an amplifier efficiency of exactly 50%. The transmitter expects to see a 50 Ω load to establish the load line for its final transistors or tubes, but its actual output impedance will generally be below 50 Ω.[5]

A tuner may, in addition, alter that output impedance significantly as it attempts to reflect as much returned energy as possible back toward the antenna. The equations and the figure in the *Handbook* would thus have to be made more complex so as to include the source impedance of the transmitter if they were to be used for insertion loss or transducer loss, and various different transmitters would cause the loss to change, making comparisons of lines and antennas difficult.

Insertion loss and transducer loss are also generally difficult to measure in the radio environment, as I pointed out in "Octave for SWR." Line loss is thus the best measure of SWR performance for Amateur Radio transmission lines, and the new figure in the *Handbook* yields total line loss, not insertion loss or attenuation.

Attenuation is generally used to describe the reduction in voltage or current along a line when the impedances are matched so that there are no reflections. Attenuation is thus formally described as a simple voltage or current ratio, usually expressed in nepers or dB, and is often used to express the loss per unit length — in the matched case — of a transmission line.[6]

I suggest that the ordinate of the new *Handbook* figure should read "Total line loss (dB)" and the caption should begin with

"Figure 20.4 — Total line loss ..." Note that the text discusses line loss and is already in agreement with these recommendations. Because Figure 20.4 includes the matched case (SWR = 1:1) at its left margin, "...Total line loss ..." would be better than "...Total mismatched line loss ...," although the latter is appropriate in the text.

— 73, Maynard Wright, W6PAP, 6930 Enright Dr, Citrus Heights, CA 95621; **w6pap@arrl.net**

Octave for Transmission Lines (Jan/Feb 2007)

Hi, Larry,

In "Octave for Transmission Lines," I introduced a *GNU Octave* expression for the input impedance of a transmission line in terms of the length of the line, its electrical characteristics, and the terminating impedance at the far end.[7, 8, 9]

```
Zd = Zo .* tanh((a .+ j .* B) .* d .+ atanh(Zt ./ Zo));
```

There is a degenerative case that may not be of much practical value, but that should probably yield a valid result for the sake of consistency: Zt = Zo. In that case, there are no reflections, the line is "flat," and Zd (the input impedance) is equal to Zo and Zt. The *Octave* code in that case reduces to:

```
Zd = Zo .* tanh((a .+ j .* B) .* d .+ atanh(1))
```

but atanh(1) is mathematically undefined in that the limit of atanh(x), as x approaches 1, is infinity.

Octave accordingly returns Inf from a call to atanh(1), indicating that the value is too large to be represented by the IEEE floating point format for numbers.[10] *Octave* does, though, allow certain operations involving Inf.[11] In this case, the hyperbolic tangent of an argument approaching infinity approaches 1, so the value 1 is returned by tanh((a .+ j .* B) .* d .+ Inf) and the result is Zd = Zo = Zt as we would expect of an actual implementation of this particular circumstance.

When we implement the same expression in *Python*, we get:[12]

```
import math
import cmath
.....
Zd = Zo * cmath.tanh((a + B * 1j) * d + cmath.atanh(Zt / Zo))
```

which, when Zt = Zo, reduces to:

```
Zd = Zo * cmath.tanh((a + B * 1j) * d + cmath.atanh(1))
```

The call to the *Python* function cmath.atanh(1) returns "Value error: math domain error" and halts execution if a script is being run.

Although we highlighted compatibilities in "Alternatives to Octave," *Octave* and *Python* behave differently in this case.[13] *Octave* conveniently allows continuation of the computation and yields a correct result, while *Python* flags an error and halts execution. It seems that neither *Octave* nor *Python* is incorrect in this matter, as the IEEE floating point standard allows several different behaviors as optional methods of exception handling, but the *Octave* result is probably more convenient for our purposes.

The exception in *Python* could be handled using the *Python* exception handling mechanism, which would allow continuation of the computation. Other alternatives, such as *C* or *C++*, should be tested for this anomaly and should be subjected to exception handling when appropriate.

— 73, Maynard Wright, W6PAP, 6930 Enright Dr, Citrus Heights, CA 95621; **w6pap@arrl.net**

Optimizing Magnetically Coupled Loop Antennas (Jan/Feb 2015)

Hi John,

I have several questions concerning your article "Optimizing Magnetically Coupled Loop Antennas," which appeared in the January/February 2015 issue of *QEX*.

Question 1: On Page 21, on the 5th line of the paragraph above the "Examples of Improved AM Broadcast Band Reception" heading, The sentence reads, "…and a = 15 inches × 0.0254 inches/cm/2 = 0.1635 m. Shouldn't the results be 0.1905 m?

Question 2: I also wonder if equation A-27 is correct. I have used the values given in the text, and try as I might, I cannot calculate the values of inductance shown in Table A-1. Nor can I verify this equation, since it doesn't seem to appear anywhere else in the articles I've found on the Internet. The primary problem appears to be the sinh(x) hypebolic function. Using the terms (PI()*a/b) returns values that are extremely large. Other references seem to use the inverse of this ratio when the coil is of large diameter and has few turns. I wonder if there is a typo.

I enjoyed the article, as I do all the others you have in *QEX* and am interested in this subject area. Thanks for your continued excellence and please keep up the good work.

— Thanks, and 73, Richard Corey, W8IMA, 7652 Lilac Dr, Jenison, MI, 49428; **w8ima.richard@sbcglobal.net**

Hi Richard,

Thank you for your questions and the diligence that they reflect.

For your Question 1: Rechecking the calculation gives 0.1905 m instead of 0.1635 m. This was apparently a typo in the manuscript for that distance, but not an error in the overall inductance calculation because I'm still getting 3.7 μH for the calculated mutual inductance for the 15 inch loop, as I reported in the article.

For your Question 2: This error occurred between my original submission and the edited version of the manuscript and I didn't catch it. Equation A-27 is calling for the inverse hyperbolic sine, sinh[-1], or asinh. Specifically, the Equation should read:

$$L = \mu_0 n^2 a\left[0.48\ln\left(1+\pi\frac{a}{b}\right)+0.52\,\mathrm{asinh}\left(\pi\frac{a}{b}\right)\right]$$

[Eq A-27]

— 73, John E. Post, KA5GSQ, Embry-Riddle Aeronautical University, 3700 Willow Creek Road, Prescott, AZ 83630; **john.post.erau.edu**

Hi Richard and John,

The error in typesetting Equation A-27 was mine. When I created the *MathType* equation in Microsoft *Word* to format it for the typesetting process, I did not notice that the program automatically inserted a space between the a and the sinh abbreviation for the hyperbolic sine function. *MathType* interpreted the "a" as a variable along with the sinh function. I should have recognized that error, and defined the asinh term as a function, as I did for the equation given above. I apologize for that error, and for the confusion that it caused.

I should also have double checked the calculations in that example on page 21 before we published the article, but I did not.

— 73, Larry Wolfgang, WR1B, QEX Editor; **lwolfgang@arrl.org**

Notes

[1]Maynard Wright, W6PAP, "Octave for SWR," *QEX*, Jan/Feb, 2009, pp 37 – 40.

[2]Maynard Wright, W6PAP, "More Octave for SWR," *QEX*, Jan/Feb, 2014, pp 31 – 33

[3]*IEEE Dictionary of Electrical and Electronics Terms*, Fourth Edition, IEEE, 1988.

[4]*Reference Data for Radio Engineers*," Fourth Edition, ITT, 1956.

[5]This does not violate the conditions for maximum power transfer because matching the load to the source yields maximum power transfer (conjugate match) only when the load is adjustable and the source is fixed. When the source is adjustable, maximum power is transferred by making the source impedance as low as possible.

[6]B. Whitfield Griffith, Jr., *Radio-Electronic Transmission Fundamentals*, McGraw-Hill, 1962, pp 203 – 204.

[7]Maynard Wright, W6PAP, "Octave for Transmission Lines," *QEX*, Jan/Feb, 2007, pp 3 – 8.

[8]For more information about *Octave*, or to download a copy of the software (Revision 3.8.1), go to the official *Octave* website: **www.octave.org**

[9]Robert A. Chipman, *Schaum's Outline Series Theory and Problems of Transmission Lines*, McGraw-Hill, Inc., 1968, p 130

[10]IEEE 754-2008, *IEEE Standard for Floating-Point Arithmetic*, The Institute of Electrical and Electronics Engineers, Inc.

[11]Be careful, though: although Inf is accepted as an argument or returned from certain trigonometric or hyperbolic functions in *Octave*, the use of Inf in arithmetic computations will lead to unexpected and incorrect results. isfloat(Inf) returns true, but Inf – Inf returns NaN rather than 0.

[12]For the latest version of *Python* (Revision 2.7.6) go to: **www.python.org**.

[13]Maynard Wright, W6PAP, "Alternatives to Octave," *QEX*, Jul/Aug, 2009, pp 25 – 27.